Using DTI to Assess the Effect of Diet or Exercise in Elderly Obese Women

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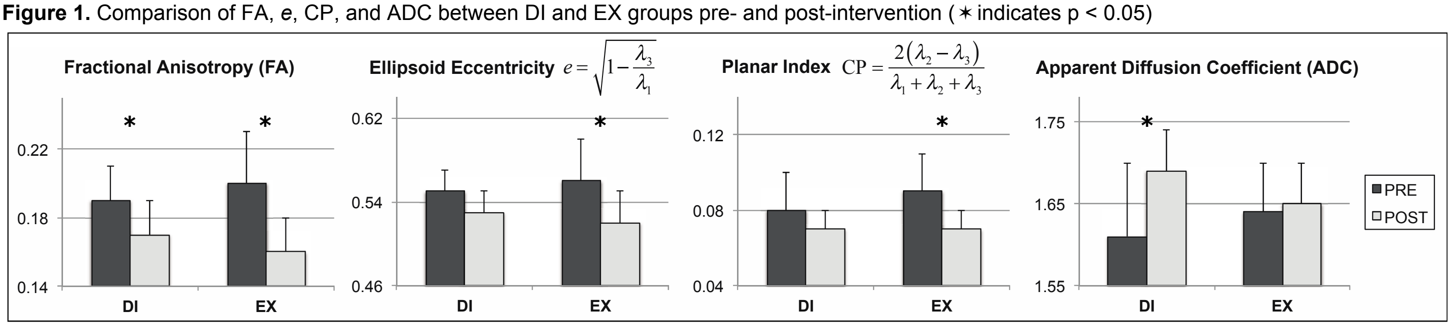
Introduction

Given the prospect of muscle biopsy, non-invasive modalities seem the obvious choice for quantifying the efficacy of various interventions aiming at improving the fitness of the increasing aging population in the USA who are obese. This study explores the sensitivity of diffusion tensor imaging (DTI) measures to perturbations of muscle quality by comparing the results of a diet or exercise intervention on the thighs of obese, elderly women. As a follow-up to a cross-sectional study of elderly women blocked on adiposity (normal weight /obese) and physical fitness (lean/sedentary) with DTI [1], this is a longitudinal study of the obese women from the cohort randomized to either a diet program or a weight-stable exercise program.

Methods

Subjects: A total of nineteen obese, elderly women (BMI: 33 ± 3, Age: 65 ± 6 years) were randomly separated into two groups and participated in either a diet-based (DI) or exercise-based (EX) intervention. With a goal of 10% weight loss in a four-month period, the DI group was placed on an energy-restricted diet (500 kcal/day restriction decreased to 1400 kcal/day over course of intervention). During the same period, the EX group participated in exercise training without caloric restriction involving three, 90-minute supervised sessions a week of combined endurance and strength training (intensity increasing from 65-75% $VO_{2,peak}$ to 70-85%).
MRI Acquisition: The subjects were scanned both pre- and post-intervention using a 3T Siemens Trio scanner. The DTI acquisition consisted of a single-shot twice-refocused spin-echo EPI sequence with the following parameters: TR/TE = 3000/71 ms, FOV = 25x25 cm^2, matrix = 76x76, seven axial slices (10mm), 10 averages, 30 directions and a b-value of 550 s/mm^2. The fat signal was suppressed with a spatial-spectral water excitation RF pulse. A combination of an eight-channel spine coil and a flexible body matrix surface coil was centered over the midpoint of the left thigh and bony landmarks were used to consistently position the imaging volume.
Analysis: A region-of-interest (ROI) was hand-drawn by a single operator containing all seven slices of the *vastus medialis* muscle, of both pre- and post-intervention scans. An ordinary linear least squares estimation of the diffusion tensor was performed using the software package, Diffusion Toolkit (version 0.6) [2], with no pre-processing of the DTI dataset. The diffusion tensor eigenvalues λ_1, λ_2, λ_3, their average value (apparent diffusion coefficient, ADC) and three non-dimensional measures, the fractional anisotropy (FA), planar index (CP), and ellipsoid eccentricity (*e*) were computed and were averaged over the ROI. An estimate of the strength of the quadriceps muscles was obtained by measuring peak torque during knee extension with a HUMAC device., and strength-related measure of muscle quality is obtained by dividing this torque by body weight [3]. Comparisons between pre- and post-intervention DTI and strength measures were performed for both DI and EX groups with a Student's t-test using unequal variances and a one-tailed distribution.

Figure 1. Comparison of FA, *e*, CP, and ADC between DI and EX groups pre- and post-intervention (∗ indicates $p < 0.05$)



Results

The results for both DI and EX groups are plotted in Figure 1 and tabulated in Table 1. Both CP and *e* showed a significant decrease for the EX group and remained unchanged for the DI group, while ADC increased for the DI group and remained constant for the EX group. Both groups saw a decrease in FA, with a more significant drop for the EX group. Unlike the DI group, the EX group had a sizeable increase (20%) in quadriceps strength.

Table 1. DTI measures with *p*-values. ADC in 10^{-9} m^2/s and TQ/Weight in arbitrary units.

	Diet Group (DI) (n = 9)			Exercise Group (EX) (n = 10)		
	PRE	**POST**	***p*-value**	**PRE**	**POST**	***p*-value**
FA	0.19 ± 0.02	0.17 ± 0.02	0.035 ∗	0.20 ± 0.03	0.16 ± 0.02	0.004 ∗
CP	0.08 ± 0.02	0.07 ± 0.01	0.159	0.09 ± 0.02	0.07 ± 0.01	0.008 ∗
e	0.55 ± 0.02	0.53 ± 0.02	0.073	0.56 ± 0.04	0.52 ± 0.03	0.007 ∗
ADC	1.61 ± 0.09	1.69 ± 0.05	0.023 ∗	1.64 ± 0.06	1.65 ± 0.05	0.322
TQ/Weight	3.9 ± 0.7	4.1 ± 0.8	0.309	3.8 ± 0.8	4.6 ± 0.9	0.039 ∗

Discussion and Conclusion

It has been established that the primary direction of diffusion and its magnitude (λ_1) correspond to diffusion in the direction of the muscle fiber [4]. Although there is a general consensus that λ_2 and λ_3 are related with the effective muscle physiological cross-sectional area (PCSA) of the muscle, the explanation for the difference between λ_2 and λ_3 is under contention [5,6]. The maximum force generation of muscle has also been experimentally related to the physiological cross-sectional area (PCSA)[7]. The ellipsoid eccentricity (*e*) has been negatively correlated with PCSA [5]. Therefore, the significant decrease in *e* for the EX group can be explained by the increase in fiber PCSA due to exercise, and the concomitant increase in maximum torque. These results demonstrate that various DTI measures can be used to quantify microstructural changes in skeletal muscle after diet- or exercise-based interventions, with exercise having a more pronounced effect on muscle structure and thus muscle quality, as expected.

References: [1] Gharibans, AA, *et al., Proc ISMRM 19,* 2011. 273; [2] Wang, R, *et al., Proc ISMRM,* 2007. 3720; [3] Villareal DT et al. *Obes Res* 12: 913-920, 2004; [4] Damon, BM, *et al., MRM*, 2002. 48:97-104; [5] Galban, CJ, *et al., Eur J Appl Physiol,* 2004. 93: 253-262; [6] Karampinos, DC, *et al., Ann Biomed Eng,* 2009. 37:2532-46; [7] Powell, PL, *et al., J Appl Physiol,* 1984. 57:1715-1721.